

A "NULL" METHOD OF MEASURING SURFACE TENSION, WITH A TORSION BALANCE.

BY S. VENKATARAMAN

PHYSICS LABORATORY, NIZAM COLLEGE, HYDERABAD-DN.

(Received for publication, June 7, 1955; received after revision, August 26, 1955)

ABSTRACT. This paper describes a "null" method for the determination of the surface tension of a liquid by the use of a torsion balance. An expression is deduced for the surface tension of a liquid, when the pull due to the surface tension acting along the perimeter of a thin glass plate (usually a microscopic cover glass slip) is balanced by the upthrust of the liquid on the partially immersed plate. The results obtained with a few liquids are reported and they agree with the values recorded in the International Critical Tables. This method yields more consistent results than any of the routine methods usually used for the measurement of surface tension.

INTRODUCTION

The method of finding the surface tension of a liquid or the surface tension at the interface of two liquids, from the force necessary to detach a thin glass plate or a horizontal ring from the surface of a liquid or the interface of two liquids is well-known and du Nouy's tensiometer (1919) and Searle's torsion balance (1934) are devices for rapid determination of the force of detachment. Recently Meier (1949) has described a "null" method for the determination of the surface tension of water using a torsion balance. In this method, the upthrust of water on a fine vertical wire immersed in it is balanced by the downward pull due to surface tension round the perimeter of the wire. He used a nichrome wire of diameter 0.0599 cm. and the pull due to surface tension along the perimeter of such a wire should be about 12 dynes for water and for most other liquids with angles of contact zero or nearly so, it should be considerably less. Although by attention to details in the construction of a torsion balance, an instrument sensitive enough to detect a pull of 0.1 dyne could be made, it would be extremely difficult to work with due to the disturbing effects of draughts and even one's breath. Curiously enough, Meier has not attempted to measure the surface tension of any liquid other than water.

The author using a torsion balance giving a deflection of 5 mm. for a pull of 0.01 gm. and thin rectangular microscopic cover glass slips and slides of various sizes, has been able to determine the surface tension of a number of liquids. The pull due to the surface tension was anything between 100 to 300 dynes depending on the liquid. Values of the surface tension of the same liquid at the same temperature in different trials, agreed to within 0.1% and their agreement with the accepted values is also quite close. Use of an external manometer to estimate the depth of immersion of the glass plate has enabled the surface tension to be determined *without any knowledge of the density of the liquid.*

EXPERIMENTAL

For this work, the sensitiveness of an ordinary Searle's type torsion balance which gives a deflection of about 2.5 mm. for a load of 0.1 gm. is insufficient and hence it was improved by replacing the torsion wire by one of steel, S.W.G. No. 30, and the torsion arm by a long thin strip of bamboo or aluminium. The length of the strip was 15" and the notch from which the glass plate was hung, was 12" from the torsion wire (figure 1). A stout piece of copper wire attached

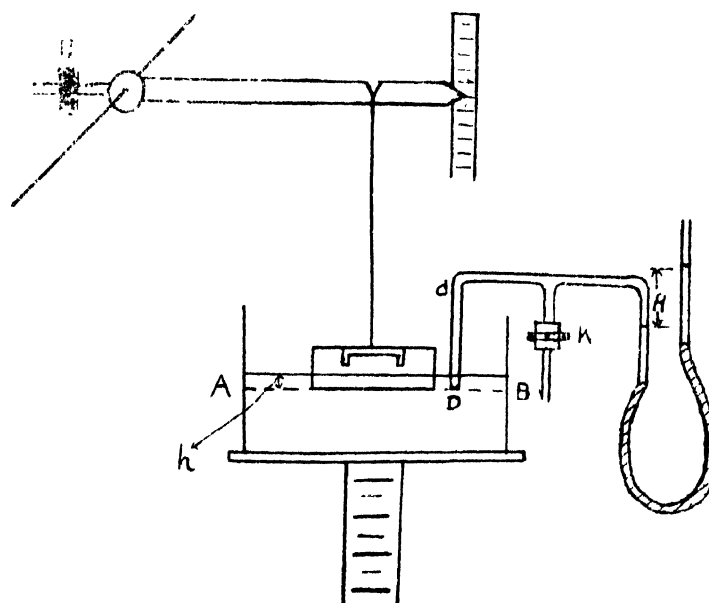


Fig. 1

to the brass screw stem carrying the torsion arm serves the same purpose as the 'gravity bob' of a sensitive chemical balance. It enables the sensitivity of the torsion balance to be increased or decreased when bent slightly up or down so as to raise or lower the C.G. of the arm. The nut *N* working in the screw stem, enables the torsion arm to be made horizontal. By suitable manipulation of

the thick copper wire, the end of the torsion arm is made to give a deflection of 5 mm. for a load of 10 mgm. at the notch. One-tenth of a scale division can be estimated by the use of a magnifying glass and so a pull of 0.2 dynes could be easily measured by the balance. The balance could, of course, be made more sensitive, but it would be difficult to work with, due to the disturbing effects of draughts.

Briefly, the method employed to determine the surface tension of a liquid is this: The liquid is contained in a wide glass crystallising dish (diameter more than 10 cm.), resting on a platform that can be raised or lowered. The torsion arm is made horizontal by working on the nut N . The dish is raised slowly till the bottom of the thin glass plate hanging from the notch of the torsion arm just comes in contact with the surface AB of the liquid and is pulled in. (The glass plate which is held by a brass clip, can be easily tilted in its holder to make its lower edge parallel to its image in the liquid). The wide vertical tube CD (diameter 1 cm.), connected to the manometer, is adjusted to bring its end D , ground flat, just in contact with the liquid surface. The clip K is closed and the open end of the manometer is raised or lowered to bring the meniscus in CD to the level of the liquid outside. The manometer is read by means of a cathetometer reading to 0.005 cm. Next, either by addition of more liquid into the dish or by raising the platform on which the dish rests and *without disturbing* CD , the torsion arm is restored back to its initial position of horizontality. The manometer is adjusted to lower the meniscus in CD to the end D , that is to say, to the original level of the liquid in the dish. The manometer is again read and the difference in its two readings gives the change of pressure at the original liquid surface AB due to the addition of liquid into the dish to restore horizontality of the torsion arm. Hence we have.

$$\gamma \cdot 2(l+t) = l t h \cdot \rho \cdot g = l \cdot t \cdot H \cdot d \cdot g$$

$$\therefore \gamma = l t H \cdot d \cdot g / 2(l+t)$$

where γ is the surface tension of the liquid, l and t length and thickness of the glass plate, ρ the density of the liquid in the dish, d the density of the manometric liquid (usually water), h the depth of immersion of the glass plate and H , the difference in the two readings of the manometer. Or, writing a for $l t$ and p for $2(l+t)$, we have

$$\gamma = a \cdot H \cdot d \cdot g / p$$

an expression free from ρ (density of the liquid) and h (depth of immersion of the plate).

RESULTS

Using this expression, the surface tensions of a few liquids were determined with glass plates of different dimensions. Chemically pure liquids from freshly

TABLE I
Liquid in the manometer is water (Density at 30°C = 0.996 gm/cc.) 'g' = 978 cm/sec².

Liquid	Plate 1			Plate 2			Plate 3			$\gamma_{30^\circ\text{C}}$ (From I. C. T.) Dynes/cm.
	l	t	a	l	t	a	l	t	a	
	2.600 cm.	$t = 0.098$ cm.	$a = 0.2548$ cm ²	7.55 cm.	$t = 0.146$ cm.	$a = 1.103$ cm ²	2.55 cm.	$t = 0.146$ cm.	$a = 0.3723$ cm ²	
	$p = 5.396$..			$p = 15.392$..			$p = 5.392$..			
	H (cm.)	$\gamma_{30^\circ\pm 1^\circ\text{C}}$ (Dynes/cm.)		H (cm.)	$\gamma_{30^\circ\pm 1^\circ\text{C}}$ (Dynes/cm.)		H (cm.)	$\gamma_{30^\circ\pm 1^\circ\text{C}}$ (Dynes/cm.)		
Water	1.550	71.29		1.02	71.17		1.06	71.29		71.18 \pm 0.05

TABLE II
Liquid in the manometer is water (Density at 30°C = 0.996 gm/cc.) 'g' = 978 cm/sec².

Liquid	Plate 1			Plate 2			Plate 3			γ (From I. C. T.) (Dynes/cm.)
	l	t	a	l	t	a	l	t	a	
	2.600 cm.	$t = 0.098$ cm.	$a = 0.2548$ cm ²	2.17 cm.	$t = 0.025$ cm.	$a = 0.0543$ cm ²	2.890 cm.	$t = 0.010$ cm.	$a = 0.0289$ cm ²	
	$p = 5.396$..			$p = 4.39$..			$p = 5.86$..			
	H (cm.)	$\gamma_{30^\circ\pm 1^\circ\text{C}}$ (Dynes/cm.)		H (cm.)	$\gamma_{30^\circ\pm 1^\circ\text{C}}$ (Dynes/cm.)		H (cm.)	$\gamma_{30^\circ\pm 1^\circ\text{C}}$ (Dynes/cm.)		
Water	1.550	71.29								71.18 \pm 0.05
Benzene	0.600	27.63		2.310	27.68		5.685	27.60		27.56 \pm 0.05
Carbon Tetrachloride	0.575	26.53		2.205	26.55		5.460	26.51		26.53 \pm 0.1
Toluene	0.595	27.39		2.270	27.32		6.625	27.36		27.30 \pm 0.1
Chloroform	0.565	26.01		2.160	26.00		5.360	26.02		27.24 \pm 0.1 (at 20 °C)
Carbon disulphide	0.675	31.09		2.580	31.06		6.390	31.03		32.23 \pm 0.20 (°C)
Olive oil	0.715	32.93		2.740	32.98					

opened bottles were used. The water used was distilled immediately before use and particular care was taken to avoid contamination by grease. The results are recorded in Tables I and II.

Writing the expression for the surface tension in the form

$$p/a = (d.g/\gamma).H$$

we notice that the graph of p/a (for different plates) against H , should be a straight line; and this is indeed the case (figure 2).

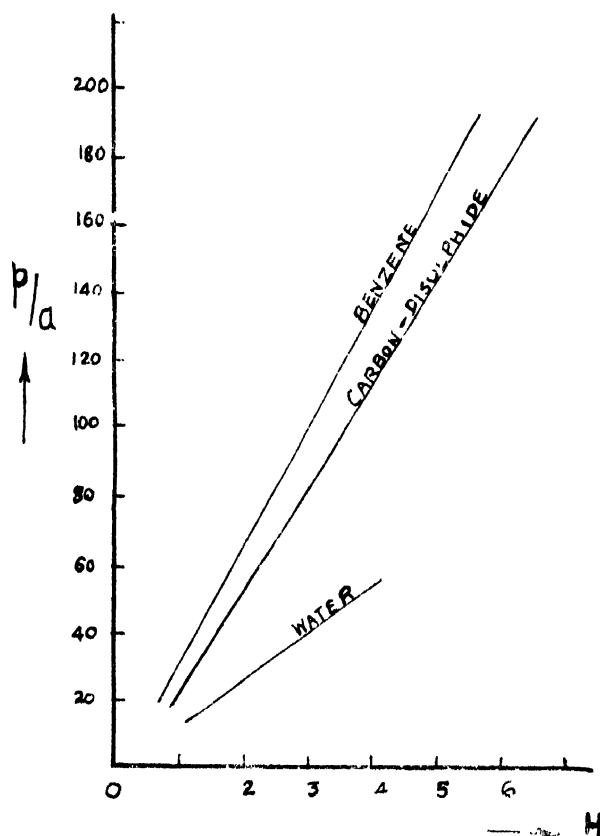


Fig. 2

It is proposed to extend this method to the determination of the surface tension at the interface of two immiscible liquids and the results obtained will be communicated later.

REFERENCES

- du Nouy, P. L., 1919, *Jour. Gen. Physiol.*, **1**, 521.
 Meier, F. A., 1949, *School Science Review*, **30**, 112.
 Searle, G. F. C., 1934, *Experimental Physics* (Cam. Univ. Press).